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New Directions in Roof Rat Control in Hawaiian Macadamia Orchards: Research Leading to an Integrated Pest Mangement Plan for this Pest Species

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Roof rats *(Rattus rattus)* resident in Hawaiian macadamia orchards (*Macadamia integrifolia*) live in an environment that provides them abundant cover and food (Tobin 1992a). The cavities and crevices in the lava rock substrate of most Hawaiian macadamia orchards provide resident rats ample harborage (e.g. nests and burrows). Interlocking branches facilitate safe movement of rats among mature macadamia trees. If food supplies within a macadamia orchard are inadequate, windbreaks and adjacent noncrop wastelands provide alternative food.

Roof rats damage an estimated 5 to 10% of the annual Hawaiian macadamia crop (Fellows 1982). During the 1995 crop year, Hawaii's growers produced 52.5 million pounds net wet-in-shell macadamia nuts valued at $36 million (Hawaii Agricultural Statistics Service, 1996 cited in Tobin et al., 1997a). This would mean that projected farm value losses due to rats in Hawaii in 1995 ranged between $1.8 and $ 3.6 million.

Staff of the National Wildlife Research Center Hawaii Field Station have conducted long-term research with a primary goal being the reduction of rodent depredation in Hawaiian macadamia orchards (Fellows 1982; Fellows et al., 1978, 1988; Pank et al., 1978; Tobin 1992a, 1992b, 1995; Tobin et al., 1993, 1994, 1996, 1997a, 1997b). One goal of this research has been to supply macadamia farmers with an integrated pest management plan for roof rats that would reduce the impact of this pest species in a cost-effective, ecologically sound manner.

The goal of this presentation is to review several research findings that will aid managers in understanding the relationship between roof rat biology and macadamia crop cycles and the implications of this information for better rat control in macadamia orchards.

Relative Importance of Macadamia Nuts in Roof Rat Diets in Macadamia Orchards

During an eleven-month period between June 1990 and April 1991 roof rats were collected from a macadamia orchard near Hilo, Hawaii to determine relative dietary composition (Tobin 1995; Tobin et al., 1994). All 199 rats (mean monthly number of rats collected = 18, SE = 1.9) collected for this study had macadamia nuts in their stomachs. Macadamia nuts were the major item in all stomachs examined. Fragments of macadamia nuts were present in stomach samples with an average relative abundance of 85% (SE = 2%, N = 11 months). Insect fragments were present in 66% of all rat stomachs and had an average relative abundance of 8% (SE = 2%, N = 11 months). Moss sporophytes, seta or capsules were present in 48% of all rat stomachs and had an average relative abundance of 4% (SE = 1%, N = 11 months). Non-moss vegetation, fruit seeds, and non-insect animal matter occurred in minor amounts (average relative abundance < 1%). The results of this study strongly support the observation that roof rats foraging within macadamia orchards use nuts as a primary food resource. Certainly, roof rat depredation could seriously impact macadamia nut yield and quality.

Effects of Roof Rat Trapping on Rat Populations, Nut Damage, and Yield of Macadamia Nuts

The effect of intensive snap trapping on roof rat populations in a macadamia orchard near Hilo, Hawaii was evaluated during the 1990 - 1991 and 1991 - 1992 crop cycles (Tobin 1992a, Tobin et al., 1993). Nut damage and macadamia yield were compared between sites where roof rat populations had and had not been controlled. As expected, roof rat abundance declined appreciably where snap trapping was undertaken. The control of roof rats in selected macadamia orchards reduced cumulative rat damage in trapped sites compared to reference sites during both crop seasons. Surprisingly, trapping had no effect on macadamia yields at harvest: the number of nuts, mass per unit and the total mass of undamaged nuts did not differ between the trapped and reference sites. These results suggest that researchers and managers should examine crop yield more closely when assessing the efficacy of roof rat control in macadamia orchards. Additionally, indices such as the proportion of nuts damaged by rats may exaggerate the ultimate effectiveness of rat control measures in Hawaiian macadamia orchards.

The Effect of Simulated Rat Damage on Yields of Macadamia Trees

The previous study prompted researchers into further investigation of the effect of rat damage on the yields of macadamia trees (Tobin et al., 1997a). During the 1995 crop season, a simulated rat damage study was conducted at two locations on the island of Hawaii. Ten to 30% of the developing nut clusters were removed from selected 5 year-old trees at 90, 120, or 150 days post-anthesis (dpa). Mature nut yield for all macadamia trees used in this experiment was measured at harvest (210 -215 dpa). Removal of 10% of developing nut clusters, regardless of timing, had no measurable effect on yield compared to a control group. Similar results were also observed for trees where 30% nut clusters were removed at 90 and 120 dpa. Significant differences were observed between treated trees and control trees when 30% of nut clusters were removed at 150 dpa. Overall, these results suggest that growers should focus efforts to manage rodent damage during later phases of nut development (>150 dpa). However, if rodent populations are extremely high and damage levels exceed 30% of nut clusters earlier in the crop cycle, macadamia trees may be less likely to compensate for this damage. In such situations, rodent control should be focused earlier in the crop cycle. We are currently initiating a second experiment to investigate the impact of simulated rodent damage during the later phases of nut development (> 150 dpa), when the impact of high levels of rodent damage may have greater impact on the yield of macadamia trees.

Movements Patterns and Seasonal Activity of Roof Rats in Hawaiian Macadamia Orchards

Radio transmitters were placed on 54 rats between November 1991 and May 1992 to determine movement patterns and seasonal activity in a macadamia orchard near Hilo, Hawaii (Tobin1995; Tobin et al., 1996). The mean minimum convex polygon home ranges for all roof rats radio collared was 0.2 ha (SE = 0.02) with no significant difference ($F = 1.93; 1, 48; P = 0.017$) in home range detected between males (0.22 ha, SE = 0.02, N = 21) and females (0.18 ha, SE = 0.025, N = 33). Similarly, no significant differences were observed in rat home ranges for both sexes among the three seasons (peak harvest, peak anthesis, and midseason) of the macadamia crop cycle ($F = 0.62; 2, 48$ df, $P = 0.54$). It is interesting to note that no rats were located on the ground during this foraging study. All radio-collared rats were located either in trees or in burrows. This result led researchers to question the efficacy of the common practice of broadcast baiting of zinc phosphide coated oat groats in Hawaiian macadamia orchards and stimulated the following study.

Bait Placement and Acceptance by Rats in Macadamia Orchards

Using a non-toxic oat bait treated with a 0.75% tetracycline hydrochloride (THC) marker, researchers determined effectiveness of differing bait placement for roof rats in macadamia orchards (Tobin et al., 1997b). THC-marked baits were broadcast on the ground, placed in burrows on the ground, and put in branch crotches in trees in macadamia orchards located in three regions on the island of Hawaii (Keaau, Hamakua, and Kona). Due to substrate differences between study sites, THC-treated baits were placed only in rat burrows at two study sites (Keaau and Kona). Thirteen to 18 days following bait placement, rats were snap trapped in treated orchards to determine the proportion of marked rats associated with differing baiting regimes. Orchards where THC-treated bait was placed in trees had the greatest percentage of marked animals (Keaau 91%, Hamakua 79%, and Kona 70%), while orchards where THC-treated bait was broadcast on the ground had the lowest efficacy (Keaau 36%, Hamakua 11%, and Kona 0%). Placement of bait in rat burrows had an intermediate level of effect (Keaau 70% and Kona 57%). These results suggested that the placement of toxic bait in trees is the most effective way to control roof rats in the macadamia orchards. Additionally, these results show that the broadcast baiting of rodenticides on the ground in macadamia orchards without interior ground vegetation is ineffective.

Conclusion

To design an effective integrated pest management plan for roof rats in Hawaiian macadamia orchards, the relationship of roof rat abundance and the crop's life cycle needs to be understood. Past and present research by staff of the National Wildlife Research Center Hawaii Field Station have been directed toward this goal. Past research efforts have identified several key points leading to a successful integrated pest management plan for roof rats in macadamia orchards. First, roof rats are the primary rodent pest species of concern for macadamia producers. Second, broadcast baiting of rodenticides on the ground in macadamia orchards without interior vegetation is ineffective for roof rat control. Third, macadamia trees can compensate for rodent damage early in the crop cycle. Presently, Hawaii Field Station staff are examining the potential for registration (United States Environmental Protection Agency 24c registration) of anticoagulant rodenticide use in bait boxes in macadamia trees. If such registrations are developed, they could provide macadamia producers with a precise technique to control roof rat damage at the sites where it occurs.

Continuation of damage simulation studies will help farmers determine economically significant thresholds for employing measures to control rat depredation in Hawaiian macadamia orchards. We have just completed a two-year study of the relationship between roof rat seasonal abundance, macadamia flowering, and nut production in three regions on the island of Hawaii that will allow farmers to tailor their rodent control plans to their specific situations. Each of these steps, supported by data from past research, will facilitate the development of an integrated pest management plan for roof rats in Hawaiian macadamia orchards.

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